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Combined therapies with nanostructured carbon materials: There is room still available at the bottom

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Abstract

© 2018 The Royal Society of Chemistry. The progress of the chemistry of carbon nanotubes (CNT) and graphene derivatives [mainly graphene oxide (GO)] has produced a number of technologically advanced drug delivery systems (DDS) that have been used in the field of nanomedicine, mostly in studies related to oncology. However, such a demanding field of research requires continuous improvements in terms of efficiency, selectivity and versatility. The loading of two, or more, bioactive components on the same nanoparticle offers new possibilities for treating cancer, efficiently addressing issues related both to biodistribution and pharmacokinetics. Nanostructured carbon materials (NCM), with their high surface area, their efficient cellular membrane crossing and their chemical versatility are ideal candidates for easy hetero-decoration and exploitation as advanced DDS. This review describes the achievements obtained in this area focusing on those studies in which two or more active components were loaded onto the DDS.

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References

[1] Making and Exploiting Fullerenes, Graphene, and Carbon Nanotubes, Topics in Current Chemistry, ed., M. Marcaccio, and, F. Paolucci, Springer, 2014, vol. 348

[2] V. Georgakilas M. Otyepka A. B. Bourlinos V. Chandra N. Kim K. C. Kemp P. Hobza R. Zboril K. S. Kim Chem. Rev. 2012 112 6156 6214

[3] D. M. Guldi and N. Martín, Carbon Nanotubes and Related Structures: Synthesis, Characterization, Functionalization, and Applications, 2010

[4] K. Kostarelos L. Lacerda G. Pastorin W. Wu S. Wieckowski J. Luangsivilay S. Godefroy D. Pantarotto J.-P. Briand S. Muller M. Prato A. Bianco Nat. Nanotechnol. 2007 2 108 113

[5] G. Reina J. M. González-Domínguez A. Criado E. Vázquez A. Bianco M. Prato Chem. Soc. Rev. 2017 46 4400 4416

[6] D. Pantarotto J.-P. Briand M. Prato A. Bianco Chem. Commun. 2004 16

[7] X. Cui B. Wan Y. Yang X. Ren L.-H. Guo Sci. Rep. 2017 7 1518

[8] M. Orecchioni R. Cabizza A. Bianco L. G. Delogu Theranostics 2015 5 710 723

[9] H. Y. Mao S. Laurent W. Chen O. Akhavan M. Imani A. A. Ashkarran M. Mahmoudi Chem. Rev. 2013 113 3407 3424

[10] A. Sanginario B. Miccoli D. Demarchi Biosensors 2017 7 9

[11] S. Shi F. Chen E. B. Ehlerding W. Cai Bioconjugate Chem. 2014 25 1609 1619

[12] W. Zhang C. Wang Z. Li Z. Lu Y. Li J.-J. Yin Y.-T. Zhou X. Gao Y. Fang G. Nie Y. Zhao Adv. Mater. 2012 24 5391 5397

[13] S. Lanone P. Andujar A. Kermanizadeh J. Boczkowski Adv. Drug Delivery Rev. 2013 65 2063 2069

[14] J. Russier L. Oudjedi M. Piponnier C. Bussy M. Prato K. Kostarelos B. Lounis A. Bianco L. Cognet Nanoscale 2017 9 4642 4645

[15] S. Marchesan K. Kostarelos A. Bianco M. Prato Mater. Today 2015 18 12 19

[16] H. Ali-Boucetta A. Nunes R. Sainz A. Herrero B. Tian M. Prato A. Bianco K. Kostarelos Angew. Chem., Int. Ed. 2013 52 2274 2278

[17] J. Muller M. Delos N. Panin V. Rabolli F. Huaux D. Lison Toxicol. Sci 2009 110 442 448

[18] A. Mazzaglia A. Scala G. Sortino R. Zagami Y. Zhu M. T. Sciortino R. Pennisi M. M. Pizzo G. Neri G. Grassi A. Piperno Colloids Surf., B 2018 163 55 63

[19] S. Fedeli A. Brandi L. Venturini P. Chiarugi E. Giannoni P. Paoli D. Corti G. Giambastiani G. Tuci S. Cicchi J. Mater. Chem. B 2016 4 3823 3831

[20] N. Sciortino S. Fedeli P. Paoli A. Brandi P. Chiarugi M. Severi S. Cicchi Int. J. Pharm. 2017 521 69 72

[21] N. K. Mehra A. K. Jain M. Nahar Drug Discovery Today 10.1016/j.drudis.2017.09.013

[22] Z. Chen A. Zhang X. Wang J. Zhu Y. Fan H. Yu Z. Yang J. Nanomater. 2017 2017 1 13

[23] R. M. Webster Nat. Rev. Drug Discovery 2016 15 81 82

[24] J. A. Kemp M. S. Shim C. Y. Heo Y. J. Kwon Adv. Drug Delivery Rev. 2016 98 3 18

[25] A. Babu A. Munshi R. Ramesh Drug Dev. Ind. Pharm. 2017 43 1391 1401

[26] S. Gadde Med. Chem. Commun. 2015 6 1916 1929

[27] E. Casals M. F. Gusta M. Cobaleda-Siles A. Garcia-Sanz V. F. Puntes Cancer Nanotechnol. 2017 8 7

[28] I. A. I. A. Vacchi C. C. Spinato J. J. Raya A. A. Bianco C. C. Ménard-Moyon Nanoscale 2016 8 13714 13721

[29] N. Kotagiri J. W. Kim Int. J. Nanomed. 2014 9 85 105

[30] N. R. Jacobsen P. Møller P. A. Clausen A. T. Saber C. Micheletti K. A. Jensen H. Wallin U. Vogel Basic Clin. Pharmacol. Toxicol. 2017 121 30 43

[31] T.-C. Chou P. Talalay Trends Pharmacol. Sci. 1983 4 450 454

[32] T. C. Chou P. Talalay Adv. Enzyme Regul. 1984 22 27 55

[33] V. Shanmugam S. Selvakumar C.-S. Yeh Chem. Soc. Rev. 2014 43 6254 6287

[34] Y.-W. Chen Y.-L. Su S.-H. Hu S.-Y. Chen Adv. Drug Delivery Rev. 2016 105 190 204

[35] M. S. Aapro Ann. Oncol. 2003 14 441 448

[36] S.-M. Lee T. V. O'Halloran S. T. Nguyen J. Am. Chem. Soc. 2010 132 17130 17138

[37] C. F. Chin S. Q. Yap J. Li G. Pastorin W. H. Ang Chem. Sci. 2014 5 2265 2270

[38] T. Yang Z. Wu P. Wang T. Mu H. Qin Z. Zhu J. Wang L. Sui J. Mater. Sci.: Mater. Med. 2017 28 110

[39] G. Cirillo O. Vittorio S. Hampel F. Iemma P. Parchi M. Cecchini F. Puoci N. Picci Eur. J. Pharm. Sci. 2013 49 359 365

[40] J. C. Sánchez-Rangel J. Benavides J. B. Heredia L. Cisneros-Zevallos D. A. Jacobo-Velázquez Anal. Methods 2013 5 5990

[41] O. Vittorio M. Brandl G. Cirillo U. G. Spizzirri N. Picci M. Kavallaris F. Iemma S. Hampel RSC Adv. 2014 4 31378

[42] M. H. A. Azqhandi B. V. Farahani N. Dehghani Mater. Sci. Eng., C 2017 79 841 847

[43] L. Liu Y. Wei S. Zhai Q. Chen D. Xing Biomaterials 2015 62 35 46

[44] R. Kurapati A. M. Raichur Chem. Commun. 2012 48 6013

[45] R. K. Thapa Y. Choi J. H. Jeong Y. S. Youn H. G. Choi C. S. Yong J. O. Kim Pharm. Res. 2016 33 2815 2827

[46] A. Nandi A. Mallick P. More P. Sengupta N. Ballav S. Basu Chem. Commun. 2017 53 1409 1412

[47] J.-M. Shen F.-Y. Gao L.-P. Guan W. Su Y.-J. Yang Q.-R. Li Z.-C. Jin RSC Adv. 2014 4 18473 18484

[48] Z. Song Y. Xu W. Yang L. Cui J. Zhang J. Liu Eur. Polym. J. 2015 69 559 572

[49] H. Wu J. Peng S. Wang B. Xie L. Lei D. Zhao H. Nie Mater. Technol. 2015 30 242 249

[50] Y. Cao Y. Chong H. Shen M. Zhang J. Huang Y. Zhu Z. Zhang J. Mater. Chem. B 2013 1 5602

[51] B. Jana G. Mondal A. Biswas I. Chakraborty A. Saha P. Kurkute S. Ghosh Macromol. Biosci. 2013 13 1478 1484

[52] Z. Huang P. Hwang D. S. Watson L. Cao F. C. Szoka Bioconjugate Chem. 2009 20 1667 1672

[53] M. A. Herrero F. M. Toma K. T. Al-Jamal K. Kostarelos A. Bianco T. Da Ros F. Bano L. Casalis G. Scoles M. Prato J. Am. Chem. Soc. 2010 132 1731

[54] Y. Tao E. Ju J. Ren X. Qu Biomaterials 2014 35 9963 9971

[55] X. Ding Y. Su C. Wang F. Zhang K. Chen Y. Wang M. Li W. Wang ACS Appl. Mater. Interfaces 2017 9 23353 23369

[56] A. Alhusban A. Al-Azayzih A. Goc F. Gao S. C. Fagan P. R. Somanath J. Pharmacol. Exp. Ther. 2014 350 635 645

[57] Y. Su Y. Hu Y. Wang X. Xu Y. Yuan Y. Li Z. Wang K. Chen F. Zhang X. Ding M. Li J. Zhou Y. Liu W. Wang Biomaterials 2017 139 75 90

[58] Z. Heger H. Polanska S. Krizkova J. Balvan M. Raudenska S. Dostalova A. Moulick M. Masarik V. Adam Colloids Surf., B 2017 150 131 140

[59] V. Sanz C. Tilmacîu B. Soula E. Flahaut H. M. Coley S. R. P. Silva J. McFadden Carbon 2011 49 5348 5358

[60] V. Sanz H. M. Coley S. R. P. Silva J. McFadden J. Nanosci. Nanotechnol. 2012 12 1739 1747

[61] S. Pereira J. Lee N. Rubio H. A. F. M. Hassan I. B. M. Suffian J. T. W. Wang R. Klippstein B. Ballesteros W. T. Al-Jamal K. T. Al-Jamal Pharm. Res. 2015 32 3293 3308

[62] Y. Zeng Z. Yang H. Li Y. Hao C. Liu L. Zhu J. Liu B. Lu R. Li Sci. Rep. 2017 7 43506

[63] F. Zhi H. Dong X. Jia W. Guo H. Lu Y. Yang H. Ju X. Zhang Y. Hu PLoS One 2013 8 1 9

[64] C. Wang S. Ravi U. S. Garapati M. Das M. Howell J. Mallela S. Alwarappan S. S. Mohapatra S. Mohapatra J. Mater. Chem. B 2013 1 4396

[65] X. Du C. Zhao M. Zhou T. Ma H. Huang M. Jaroniec X. Zhang S. Z. Qiao Small 2017 13 1 11

[66] H. A. F. M. Hassan L. Smyth J. T.-W. Wang P. M. Costa K. Ratnasothy S. S. Diebold G. Lombardi K. T. Al-Jamal Biomaterials 2016 104 310 322

[67] F. Yin K. Hu Y. Chen M. Yu D. Wang Q. Wang K.-T. K.-T. Yong F. Lu Y. Liang Z. Li Theranostics 2017 7 1133 1148

[68] X. Fu X. Wang S. Zhou Y. Zhang Int. J. Nanomed. 2017 12 3751 3766

[69] Y. Yang Y. Wang M. Zhu Y. Chen Y. Xiao Y. Shen A. Xie Biomater. Sci. 2017 5 990 1000

[70] H. Chen Z. Liu S. Li C. Su X. Qiu H. Zhong Z. Guo Theranostics 2016 6 1096 1104

[71] R. Dou Z. Du T. Bao X. Dong X. Zheng M. Yu W. Yin B. Dong L. Yan Z. Gu Nanoscale 2016 8 11531 11542

[72] X. Shi H. Gong Y. Li C. Wang L. Cheng Z. Liu Biomaterials 2013 34 4786 4793

[73] C. Wu Q. He A. Zhu D. Li M. Xu H. Yang Y. Liu ACS Appl. Mater. Interfaces 2014 6 21615 21623

[74] L. Zhou L. Zhou S. Wei X. Ge J. Zhou H. Jiang F. Li J. Shen J. Photochem. Photobiol., B 2014 135 7 16

[75] H. Jang M.-H. Choi Y. Yim Y.-K. Kim D.-H. Min Adv. Healthcare Mater. 2015 4 1833 1840

[76] Y. Yang S. Chen L. Liu S. Li Q. Zeng X. Zhao H. Li Z. Zhang L. S. Bouchard M. Liu X. Zhou ACS Appl. Mater. Interfaces 2017 9 23400 23408

[77] Z. Chen Z. Li J. Wang E. Ju L. Zhou J. Ren X. Qu Adv. Funct. Mater. 2014 24 522 529

[78] C. Wu D. Li L. Wang X. Guan Y. Tian H. Yang S. Li Y. Liu Acta Biomater. 2017 53 631 642